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NAVAL SHIP RESEARCH AND DEVELOPMENT CENTER

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EFFECT OF LENGTH-BEAM RATIO ON THE
PERFORMANCE OF A STEPPED PLANING BOAT
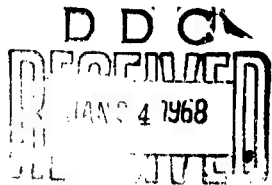## WITH AN ADJUSTABLE STERN STABILIZER

by

Eugene P. Clement

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HYDROMECHANICS LABORATORY

RESEARCH AND DEVELOPMENT REPORT

August 1967   Report No. 2552

ABSTRACT

Two models of stepped planing boats were tested to determine the effect of change in length-beam ratio. The models were tested with the same adjustable stern stabilizer at several loads and LCG locations. The model with the lower length-beam ratio (L_p/B_{PX} = 3.4) had considerably more resistance than the other stepped model (L_p/B_{PX} = 4.7) at low speed and slightly less resistance at high speed. The resistance of both stepped designs at high speed was considerably less than that of a representative unstepped planing boat design.

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A_P Projected bottom area, excluding area of external spray strips (area bounded by chines and transom in plan view)

a.b.   Afterbody

B_P Beam or breadth over chines, excluding external spray strips

B_{PA} Mean breadth over chines, A_P/L_P

B_{PT} Breadth over chines at transom

B_{PX} Maximum breadth over chines, excluding external spray strips

B.L.   Baseline

C_f Coefficient of frictional resistance

EHP   Effective horsepower

F_∇ Froude number based on volume, in any consistent units $v/\sqrt{g \nabla^{1/3}}$

g   Acceleration due to gravity

H   Draft to point of main step

L_P Overall length of the area, A_P, measured parallel to the baseline

LCG   Longitudinal center of gravity

R   Total resistance

S   Area of wetted surface (this is the actual wetted surface underway including the wetted bottom area of external spray strips; however, the area wetted by spray is excluded)

v   Speed in feet per second

V   Speed in knots

w   Weight density of water (weight per unit volume)

WL_C Intersection of forebody chine with solid water, measured from step

WL_K Wetted length of forebody keel, measured from step

WL_{SP} Intersection of forebody chine with spray, measured from step

α Angle with horizontal of tangent to straight portion of forebody keel in degrees

β Deadrise angle of planing bottom in degrees (this angle is obtained by approximating each body plan section by a straight line)

λ Linear rat', ship to model

W Displacement at rest, weight of

ρ Mass density of water

∇ Displacement at rest, volume of

Units are feet, pounds, seconds, except where shown otherwise.

Subscripts

ab   Afterbody

fb   Forebody

o   Zero speed

m   Model

s   Ship

INTRODUCTION

For a number of years, the Naval Ship Research and Development Center has been working on a particular configuration of stepped planing boat and conducting model tests to evaluate the effects of changes in the various parameters of the design. This design has a shallow step at midlength and an adjustable planing surface, or stabilizer, at the stern. The stabilizer is of the type devised by John Plum of the Center staff. At high speeds, the flow separates from the hull bottom aft of the step and the hull is then supported dynamically by a portion of the forebody and by the adjustable stabilizer. Since the afterbody bottom is unwetted at high speeds, the wetted area - and accordingly the resistance - are considerably less than for the conventional (unstepped) planing boat.

Reference 1 presented the lines and model test results for the first model of this type which was designed and extensively tested at the Center (Model 4124). Subsequently, two additional models (4335-1 and 4461) were built and tested. The latter two differ from Model 4124 chiefly in the fact that they have considerably more deadrise in the bow. These two have identical body plan sections but differ in length-beam ratio. The ratio of chine length to average chine beam is 6.9 for Model 4335-1 and 5.0 for Model 4461. Additional dimensions and coefficients for all three models are given in Table 1.

This report presents the results of resistance tests of Models 4335-1 and 4461 at various weights and LCG locations. Comparisons of the results for the two models show the effect of change in length-beam ratio on the performance of this configuration of stepped planing boat.

DESCRIPTION OF THE MODELS EMPLOYED

Figure 1 shows photographs of Model 4335, as originally constructed. Initial tests of the original model indicated that the angle of 3.0 degrees between forebody and afterbody keels was insufficient; it was therefore increased to 4.7 degrees (the same as for Model 4124 D). The hull lines of the revised model (designated 4335-1) are shown in Figure 2. The lengths of the hull components, and the location of the shaftline, are shown in Figure 3. Some preliminary testing of Model 4461 was done with different configurations of the main step. A satisfactory configuration was found, and for this case, the model was designated No. 4461-3. The lines of Model 4461-3 are shown in Figure 4.

The value of the ratio L_P/B_{PX} was 4.72 for Model 4335-1 and 3.43 for Model 4461-3. Both models consisted entirely of developable surfaces. Model 4335-1 was fitted with 1/8-inch square spray strips along the forebody and afterbody chines and Model 4461-3 was fitted with 3/16-inch spray strips. To reduce the suction forces at low speeds, each model was equipped with two 9/32-inch-diameter air ducts running from inside the hull to the vertical face of the after step. The dimensionless hull form characteristics for the models are given in Figure 5. It can be seen that these curves are nearly the same for the two models.

Both models were tested with the same model of a Plum stabilizer; the stabilizer is essentially formed as the intersection of two cylindrical surfaces meeting at an angle of 3 degrees; see Figure 6.

As explained in Reference 1, the stabilizer is connected to a piston working in a pneumatic cylinder, so that its vertical position can be controlled by compressed air. When the boat is at rest or moving at low

speeds, the stabilizer is held against the bottom of the stern extension.
In this position, the lower surface of the stabilizer is approximately paral-
lel to the afterbody keel. As the stabilizer is lowered it automatically
pivots in such a direction as to increase its angle of attack until it lies
flush against a longitudinal member (the foot) which is rigidly attached
to the piston rod of the actuating mechanism. The moment at which the
stabilizer lies against the foot coincides with the moment the leading edge
of the stabilizer comes clear of the hull bottom. Thereafter as the stabilizer
is lowered further it remains against the foot and accordingly at a fixed angle
with respect to the forebody keel. For the tests of Model 4335-1 the bottom
of the stabilizer, when lowered, was at + 1.8 degrees with respect to the
forebody keel, and for the tests of Model 4461-3 the bottom of the stabilizer,
when lowered, was at - $\frac{1}{4}$ degree with respect to the forebody keel. The de-
sign has the least resistance at the lower speeds with the stabilizer in the
retracted position. At speeds above F_∇ equals about 1.8, however, minimum re-
sistance is obtained with successively lower positions of the stabilizer. Ad-
ditional details concerning the operation of the stabilizer and a drawing of
the actuating mechanism are given in Reference 1.

MODEL TESTS AND RESULTS

The models were towed in smooth water in the shaftlines shown in Figures 3 and 4, respectively. The only appendages attached for these tests were spray strips and the stabilizer. The models were tested at various displacements and LCG locations. The quantities measured were resistance, trim, rise, and forebody and afterbody wetted lengths.

In general, it was attempted to adjust the vertical position of the stabilizer to the position for minimum resistance at each test speed. In this way, a curve of minimum resistance versus speed was obtained. Data from the tests of Model 4124 provided guidance in selecting the stabilizer settings for minimum resistance.

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Model 4335-1 was tested at a model weight of 158.5 pounds which corresponds to a value of the area coefficient $A_p/\nabla^{2/3}$ of 7.0. Tests were made at three different LCG locations. Figures 7 and 8 give the model test results in dimensionless form. The forebody and afterbody wetted lengths presented in Figure 8 were nondimensionalized by dividing the observed wetted lengths by the overall length of forebody and afterbody, respectively. The overall forebody and afterbody lengths of Model 4335-1 are given in Figure 3.

The resistance data of Figure 7 show that for this stepped hull with a stabilizer for trim control, the resistance at the higher speeds (above a F_∇ of about 2.4) is almost entirely unaffected by a shift in LCG location. The wetted length data of Figure 8 show that the wetted area of the afterbody bottom begins to diminish at about F_∇ equals 1.6 (this coincides with ventilation of the step). At all speeds above $F_\nabla = 3$, the afterbody bottom is entirely dry. The data also show that the wetted length of the forebody chine will diminish to zero at about F_∇ equals 4.8. At about that speed, therefore, the stagnation line will intersect the step, the main spray blister will wet the afterbody, and a significant drag rise will result. Satisfactorily low resistance can be maintained up to higher speeds, however, by changing the transverse step to one which is swept back, as explained in Reference 2.

Model 4461-3 was tested at weights corresponding to area coefficients of 6.85 and 6.05. The corresponding model weights were 165.3 and 198.4 pounds, respectively. In addition, tests were made at several LCG locations. Model values of resistance-weight ratio and angle of attack for the two test weights are given in Figures 9 and 10. These figures also include data showing the draft to the point of the step and the distance which the stabilizer was lowered. Both of those quantities were non-dimensionalized by dividing by $\nabla^{1/3}$. Wetted length data for the two displacements, in the same dimensionless form as was utilized for Model 4335-1, are given in Figures 11 and 12. Values of the percent of weight carried by the stabilizer are given in Figure 13.

In addition to presenting the performance data corresponding to optimum stabilizer position, Figures 10 and 12 include data (identified by symbols with tails) for a test in which the stabilizer was retracted at all speeds.

Figure 14 compares the resistance, trim, and wetted area data for
the two stepped designs and for a conventional planing boat design. The
resistance data have been corrected to correspond to 100,000 pound dis-
placement. It can be seen that decreasing the length-beam ratio (L_p/B_{PA})
of the stepped design from 6.9 to 5.0 reduced the resistance somewhat
at high speeds (presumably because of the increase in the aspect ratio
of the planing surface), but that this was accompanied by an appreciable
increase in the low speed resistance. At a value of $F_\nabla = 4.8$, the
unstepped design has 30 percent more resistance than the stepped design,
represented by Model 4335-1.

TABLE 1

Planing Bottom Dimensions and Coefficients

for Models 4124C, 4335-1, and 4461-3

	Model No.		
	4124C	4335-1	4461-3
L_p, feet	9.14	9.48	8.09
B_{PX}, feet	2.00	2.01	2.35
B_{PA}, feet	1.35	1.38	1.62
A_p, feet^2	12.29	13.1	13.1
L_p/B_{PX}	4.57	4.72	3.43
L_p/B_{PA}	6.80	6.9	5.0
Location of main step, percent L_p	49	47	47
Deadrise at main step, degrees	16	16	16
Angle of a.b. keel, degrees	3.5	4.7	4.5
Centroid of A_p, percent L_p	-	52.4	-
B_{PX}/B_{PA}	1.48	1.46	1.45
B_{PT}/B_{PX}	0.34	0.38	0.38
Angle of a.b. chine in plan view, degrees	5.0	6.0	7.6

REFERENCES

1. Clement, E. P., "Model Tests of a Stepped Planing Boat with an
    Adjustable Stern Stabilizer," Naval Ship Research and Development Center
    Report 2414 (May 1967)

2. Clement, E. P., "The Planing Characteristics of a 15-Degree Deadrise
    Surface with Circular-Arc Camber," David Taylor Model Basin Report
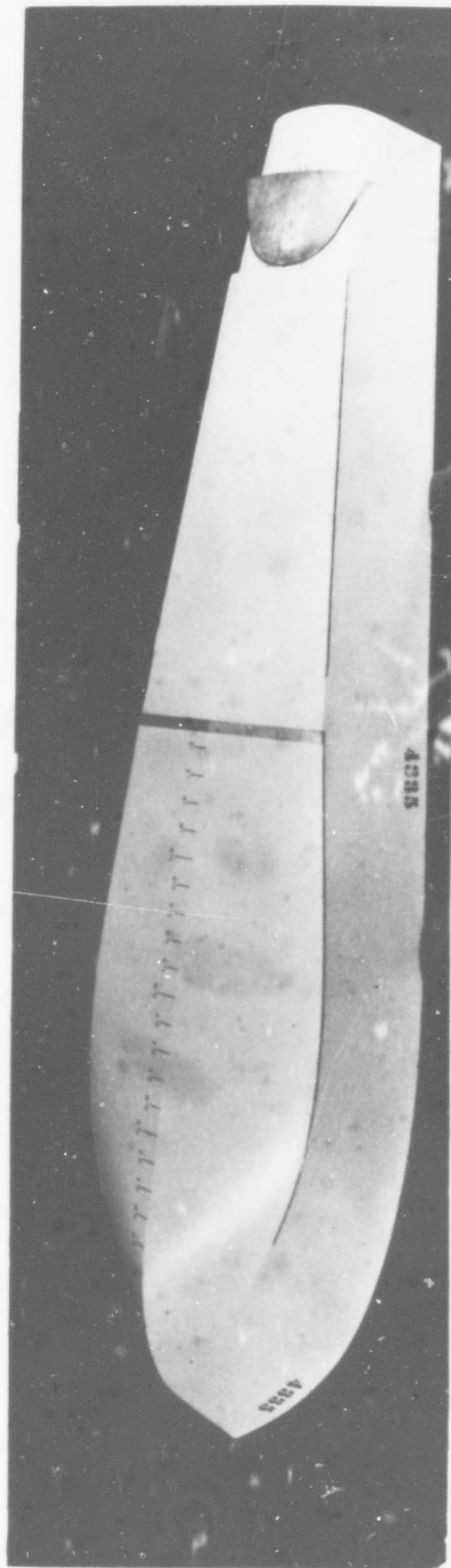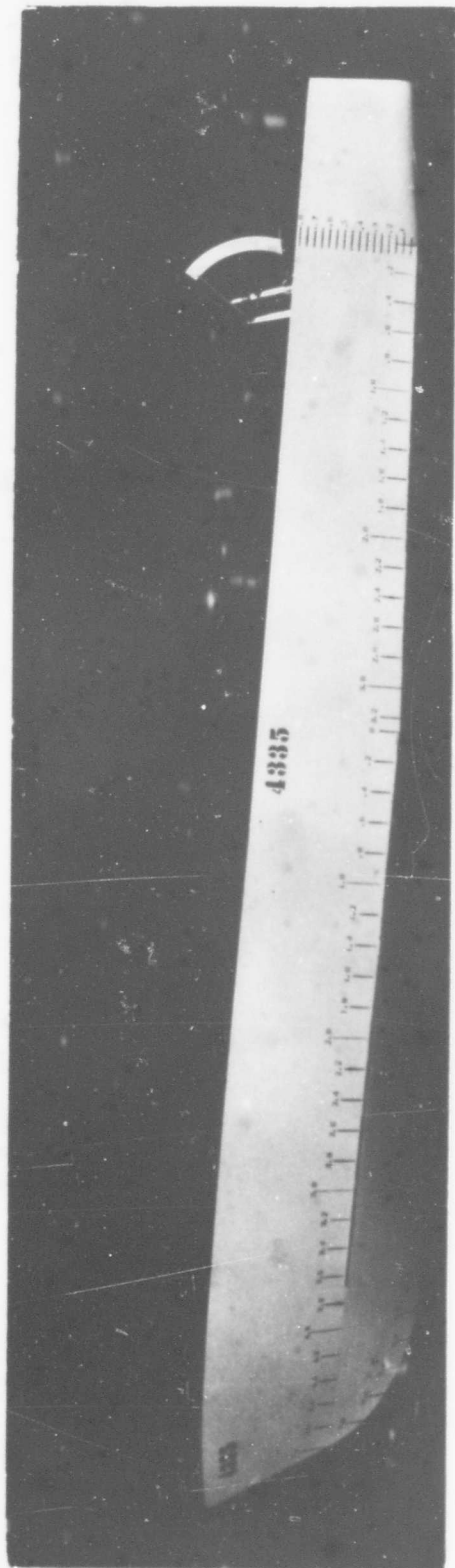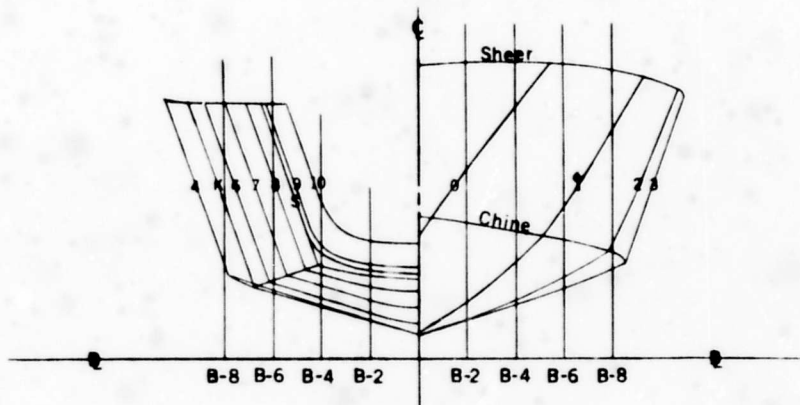   2298 (Sep 1966)

Figure 1 - Model 4335 as Originally Constructed

TMB Model No. 4335-1

Lp/Bpx = 4.72

Model Scale in Inches

0 2 4 6 8 10 12

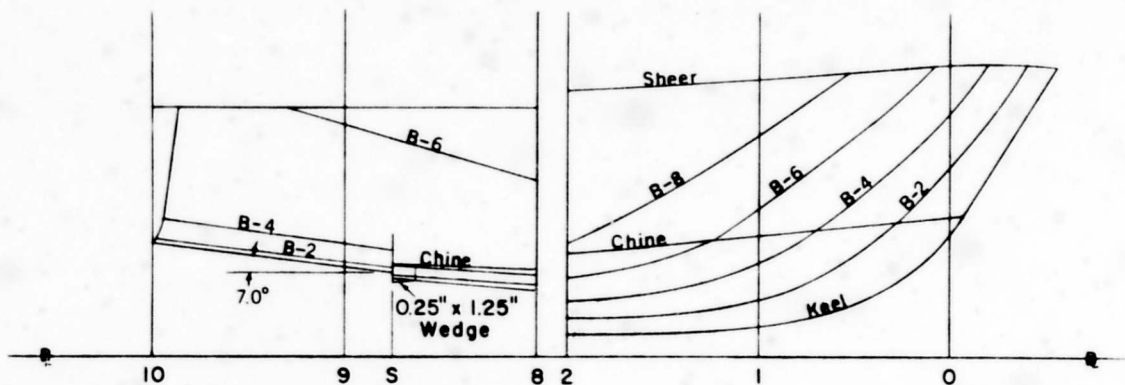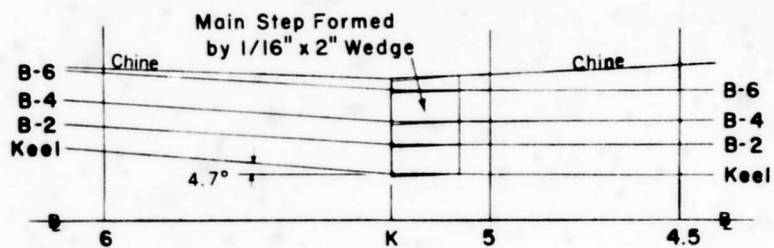Enlarged Step Section

Main Step Formed
by 1/16" x 2" Wedge

Figure 2 - Lines of Model 4335-1

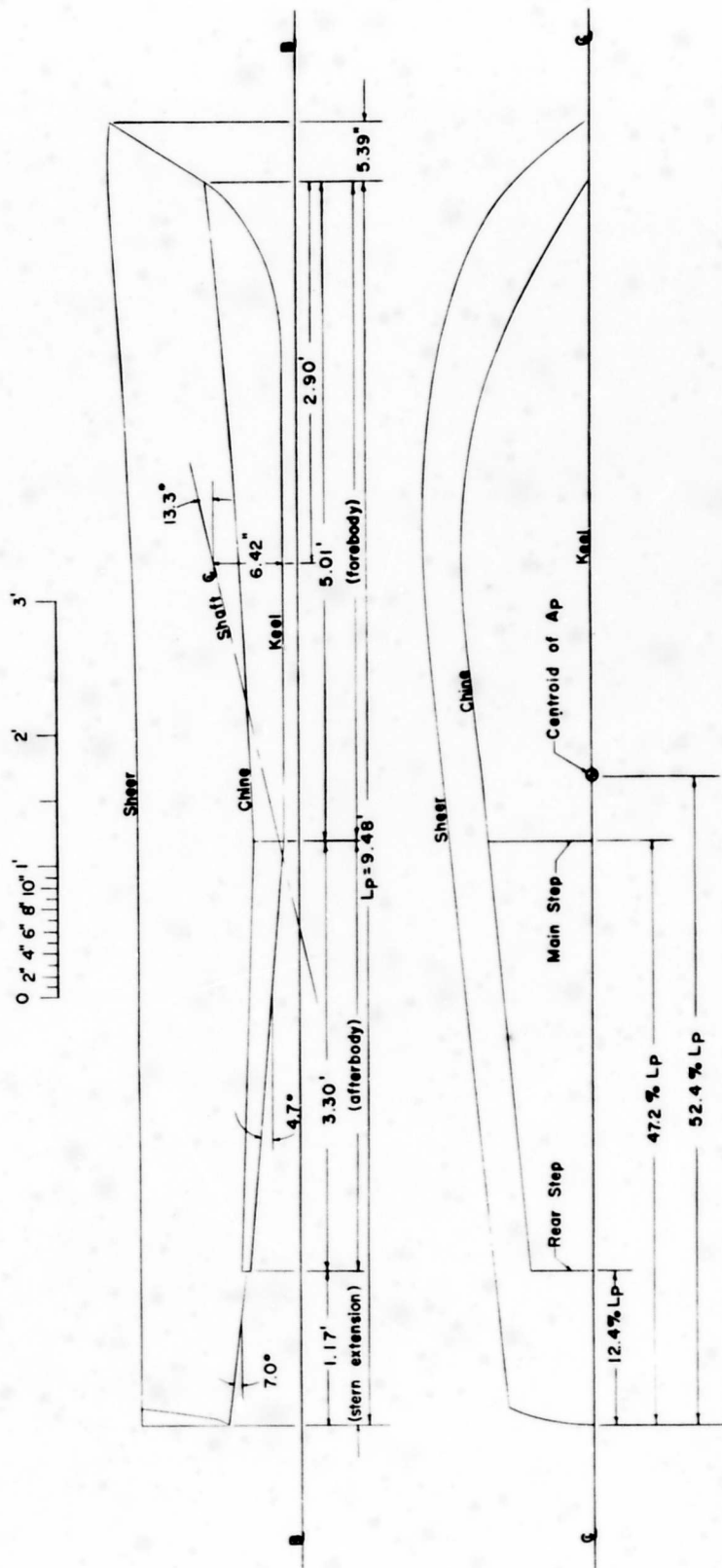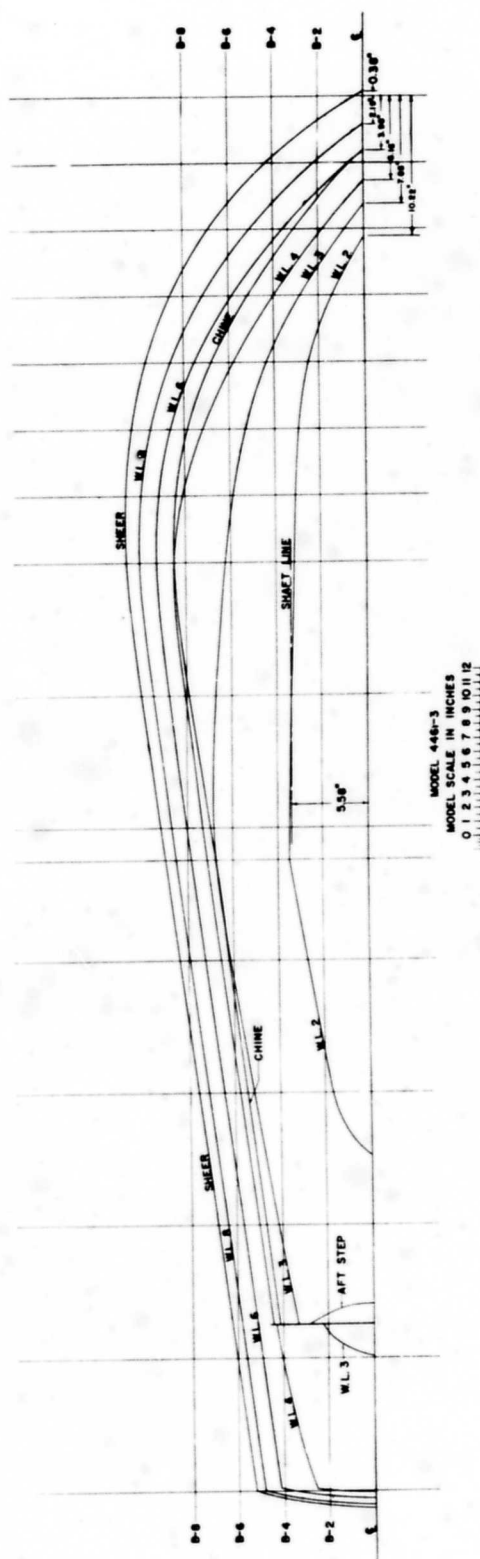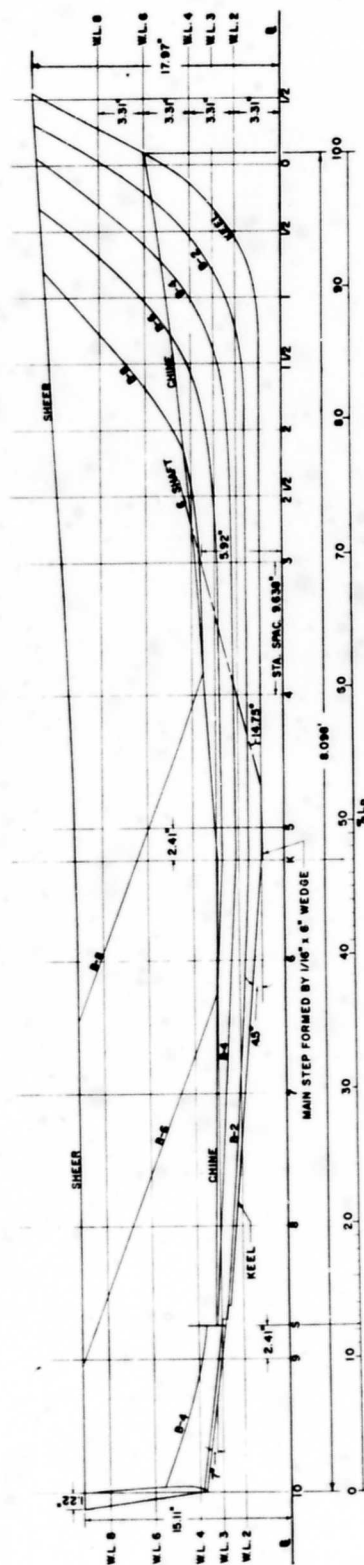Figure 3 - Lengths of Hull Components and Location
of Shaftline, Model 4335-1

Figure 4a – Profile and Plan Views

Figure 4 – Lines of Model 4461-3

-13-

MODEL 4461-3
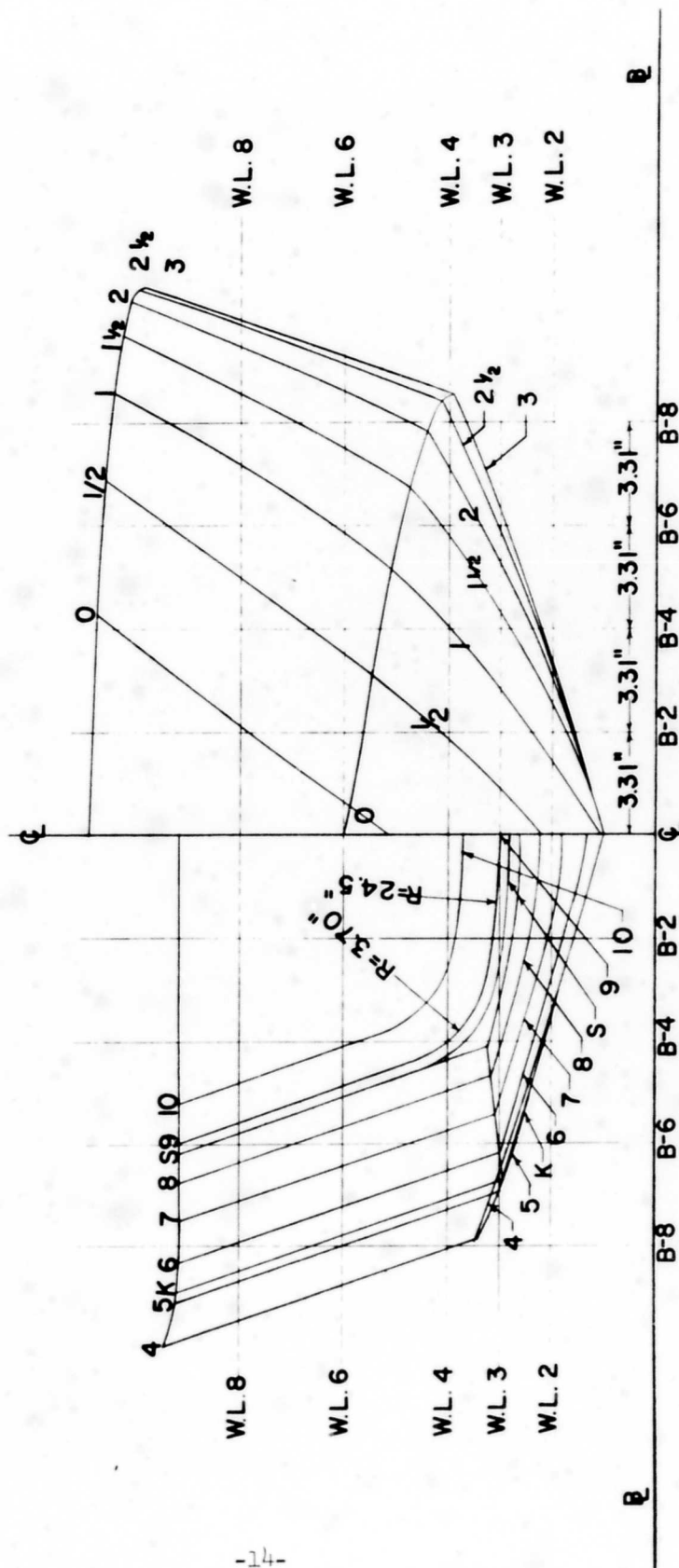MODEL SCALE IN INCHES
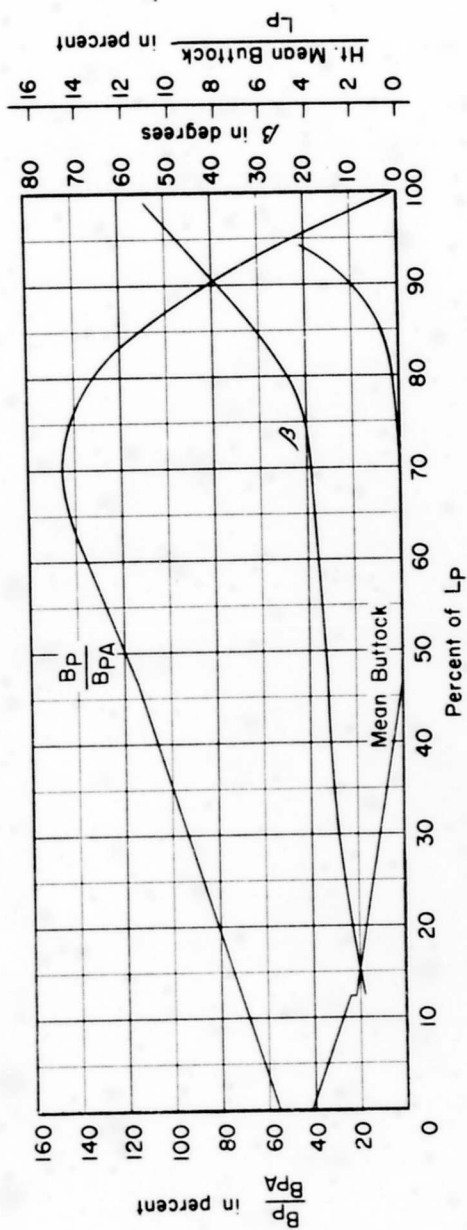0 1 2 3 4 5 6 7 8 9 10 11 12

Figure 4b - Body Plan

-14-

Figure 5a — Model 4335-1
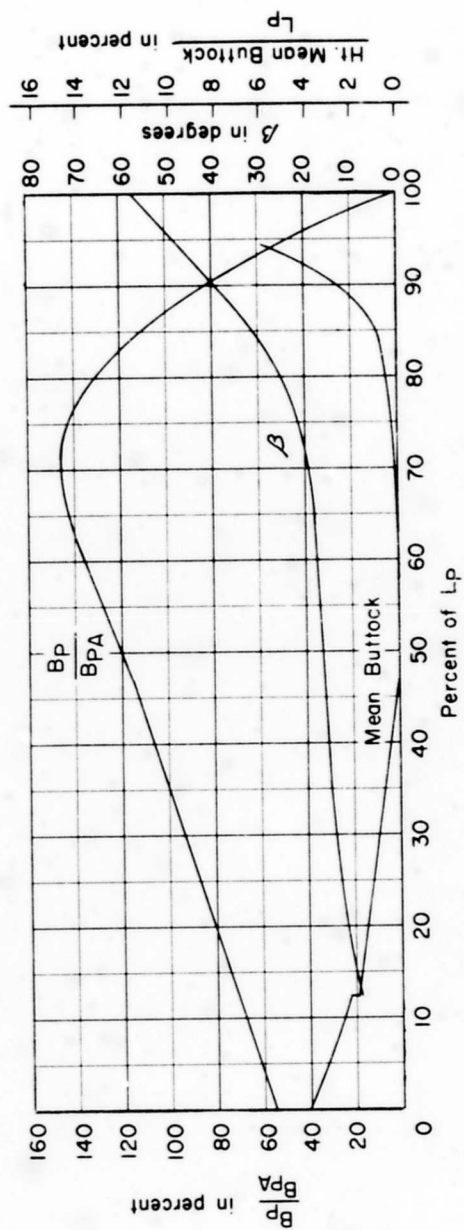
Figure 5b — Model 4461-3

Figure 5 – Dimensionless Hull Form Characteristics

Model Scale in Inches

All Joints Silver - Soldered

Section B-B

Section A-A

Section CC

Section thru ℄

⅛" Brass Plates

8.25"

3°

1/16" Brass Plate

R=5.75"

R=43.0"
R=23.83"

Channel Made of 1/16" Brass Plate

14.82"

Figure 6 - Model of the Plum Stabilizer

-16-
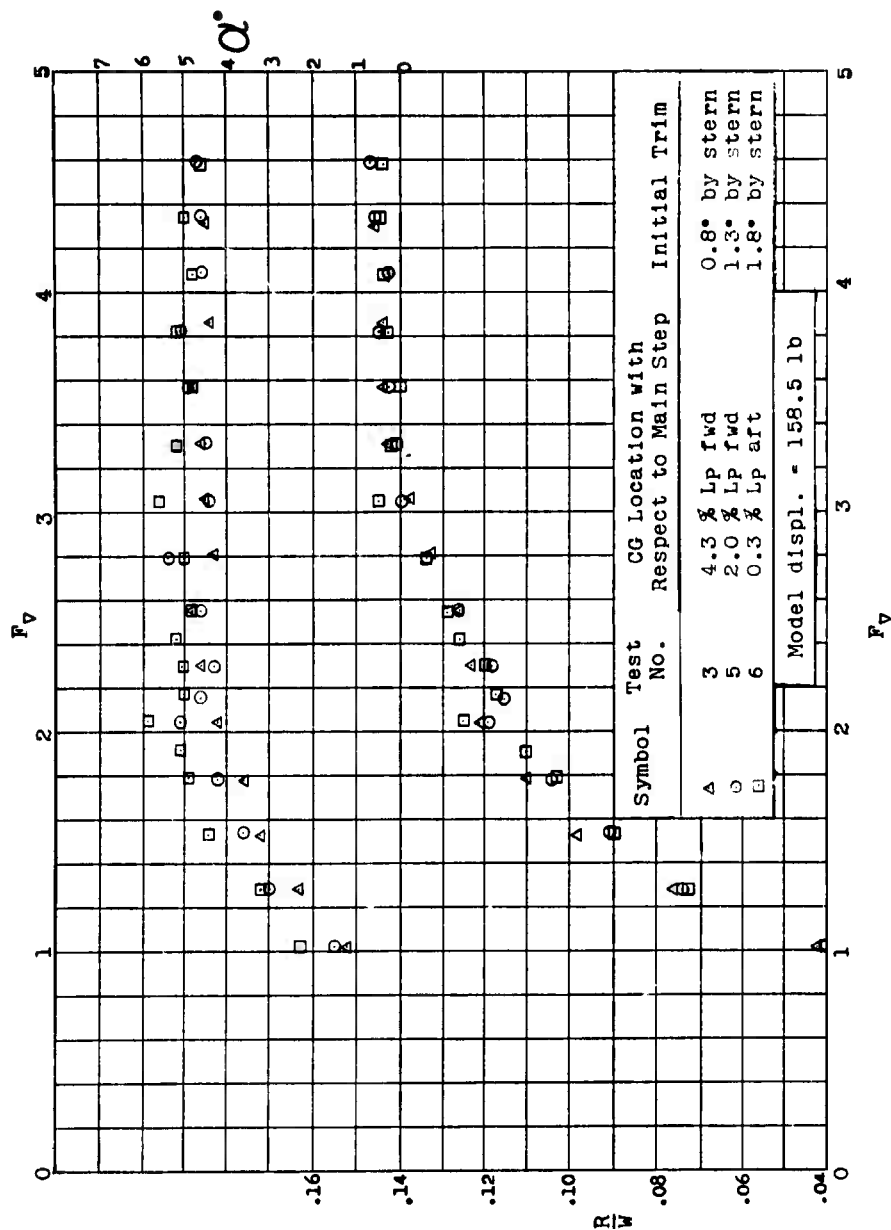
Figure 7 – Resistance and α for Model 4335-1 at Three LCG Positions, $A_p/\nabla^{2/3}=7.0$

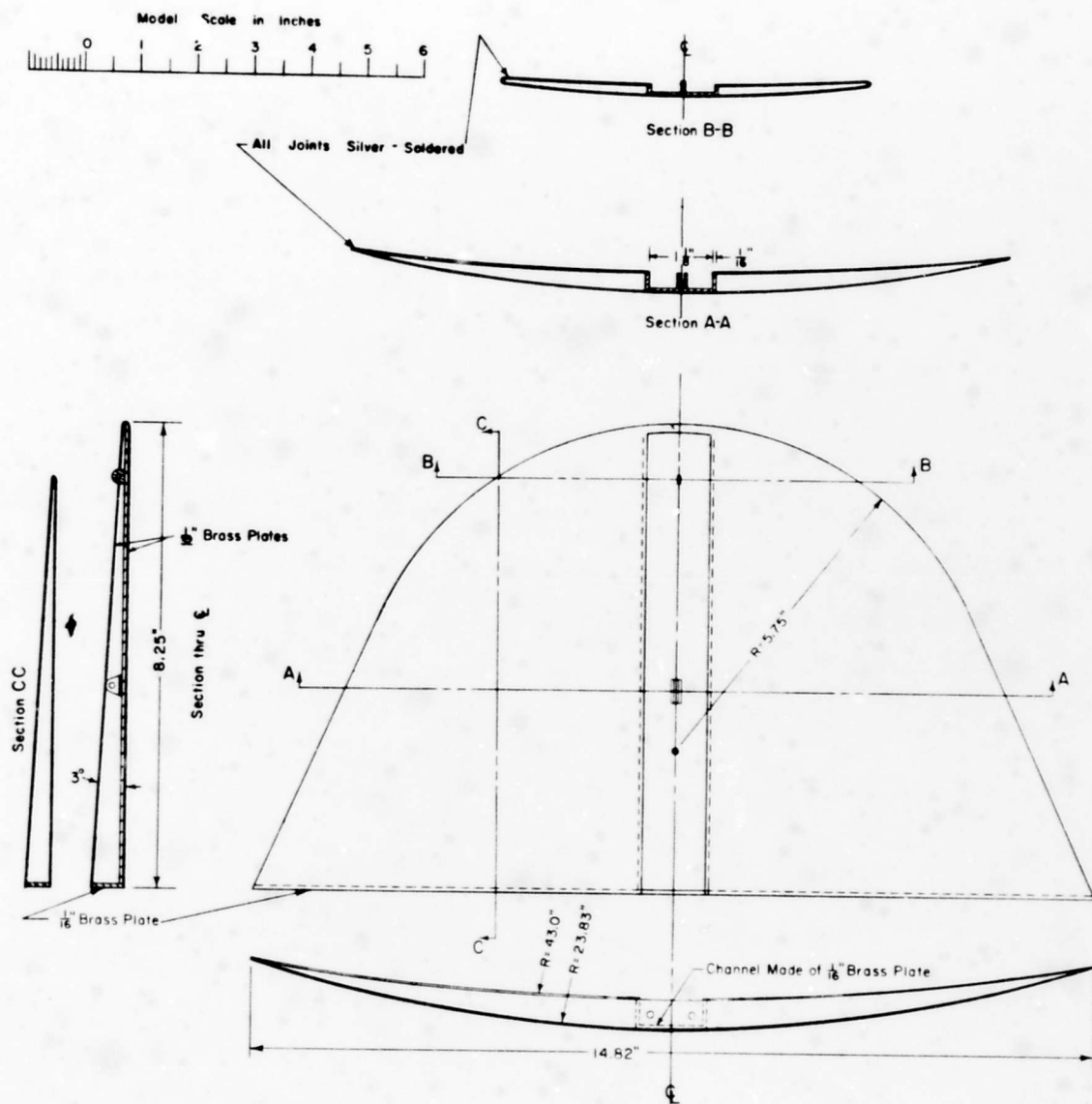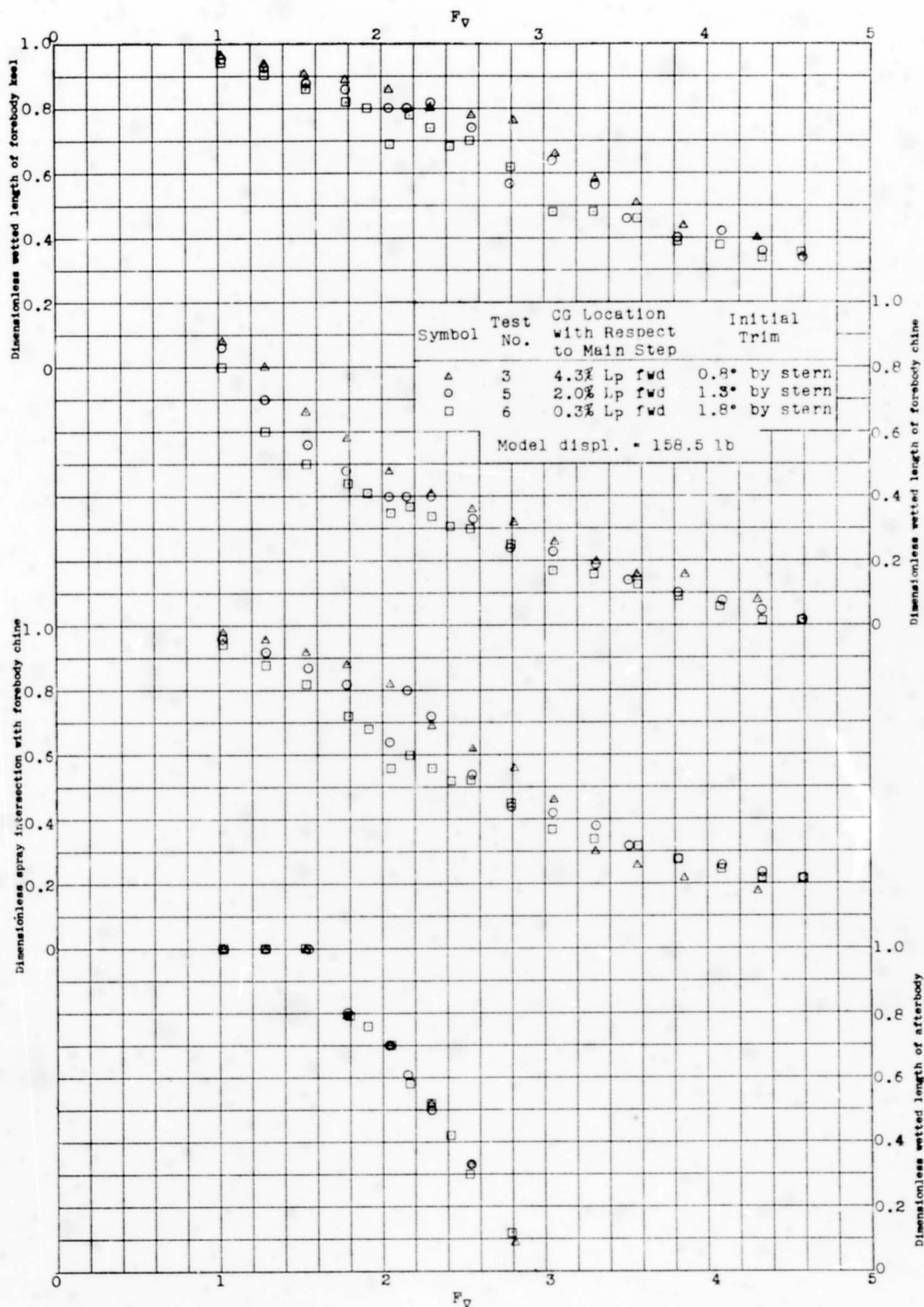Figure 8 - Wetted Lengths for Model 4335-1 at Three LCG Positions, $A_p/\nabla^{2/3} = 7.0$
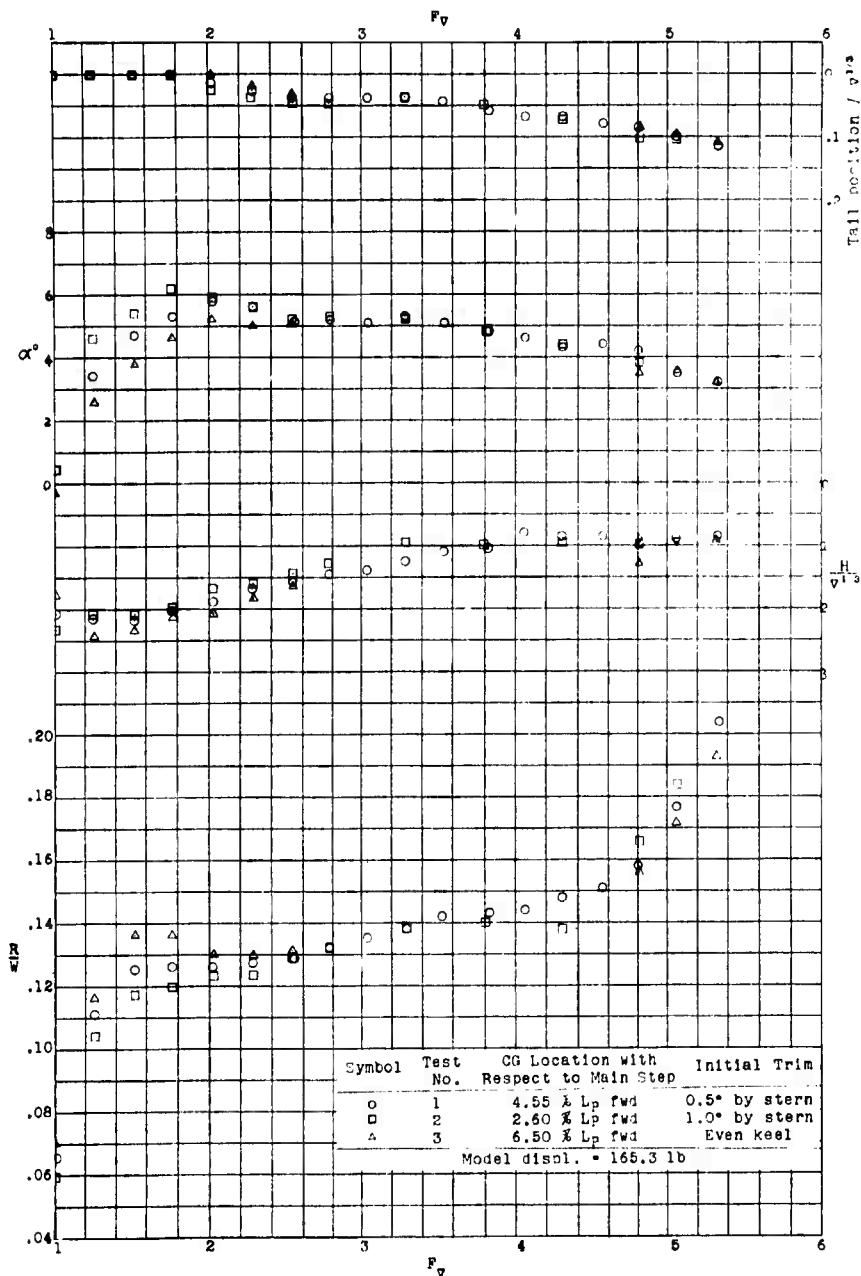
Figure 9 - Resistance, Draft, α, and Stabilizer Position for Model 4461-3 at Three LCG Positions, $A_p/\nabla^{2/3} = 6.84$

Figure 10 - Resistance, Draft, α, and Stabilizer Position for
Model 4461-3 at Two LCG Positions, $Ap/\nabla^{2/3}$ = 6.05

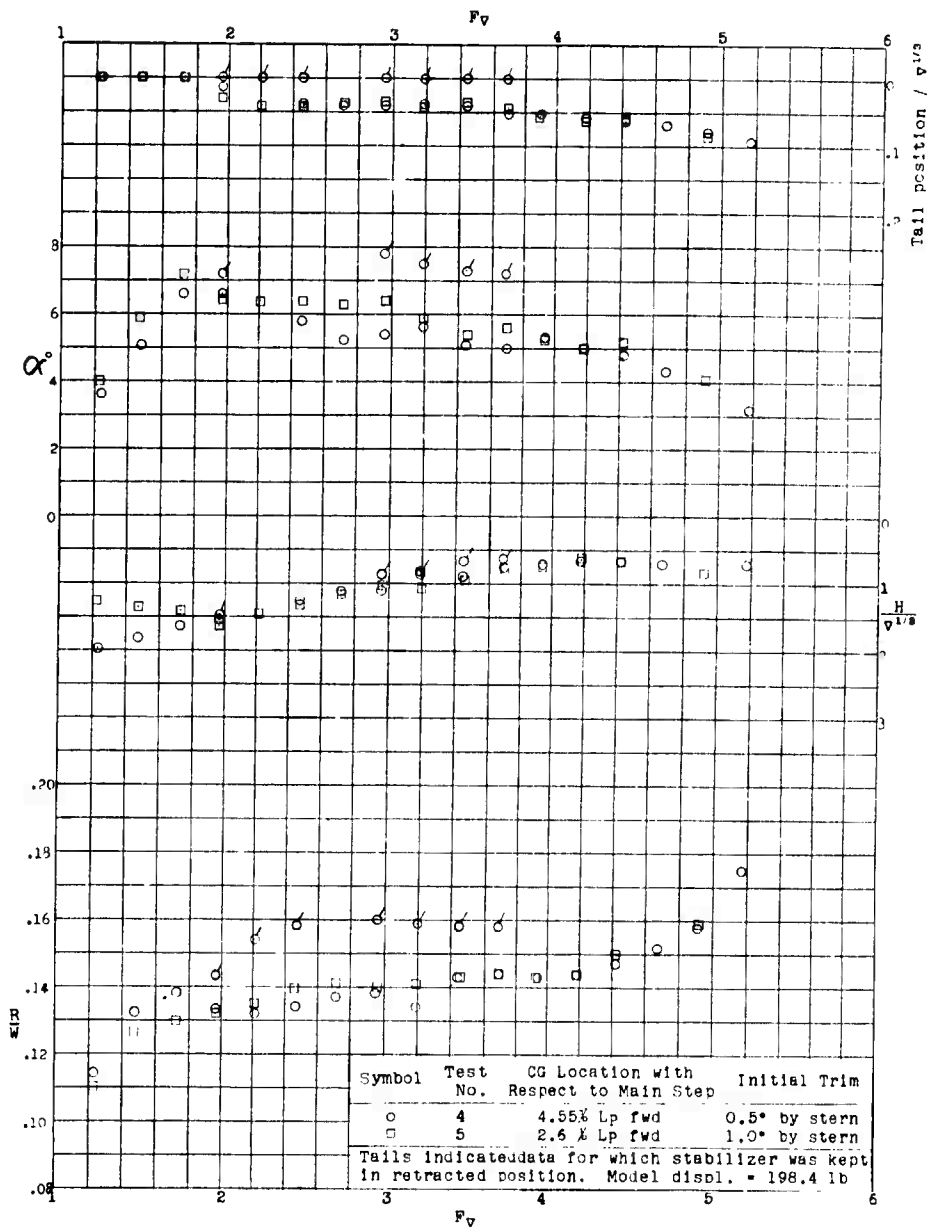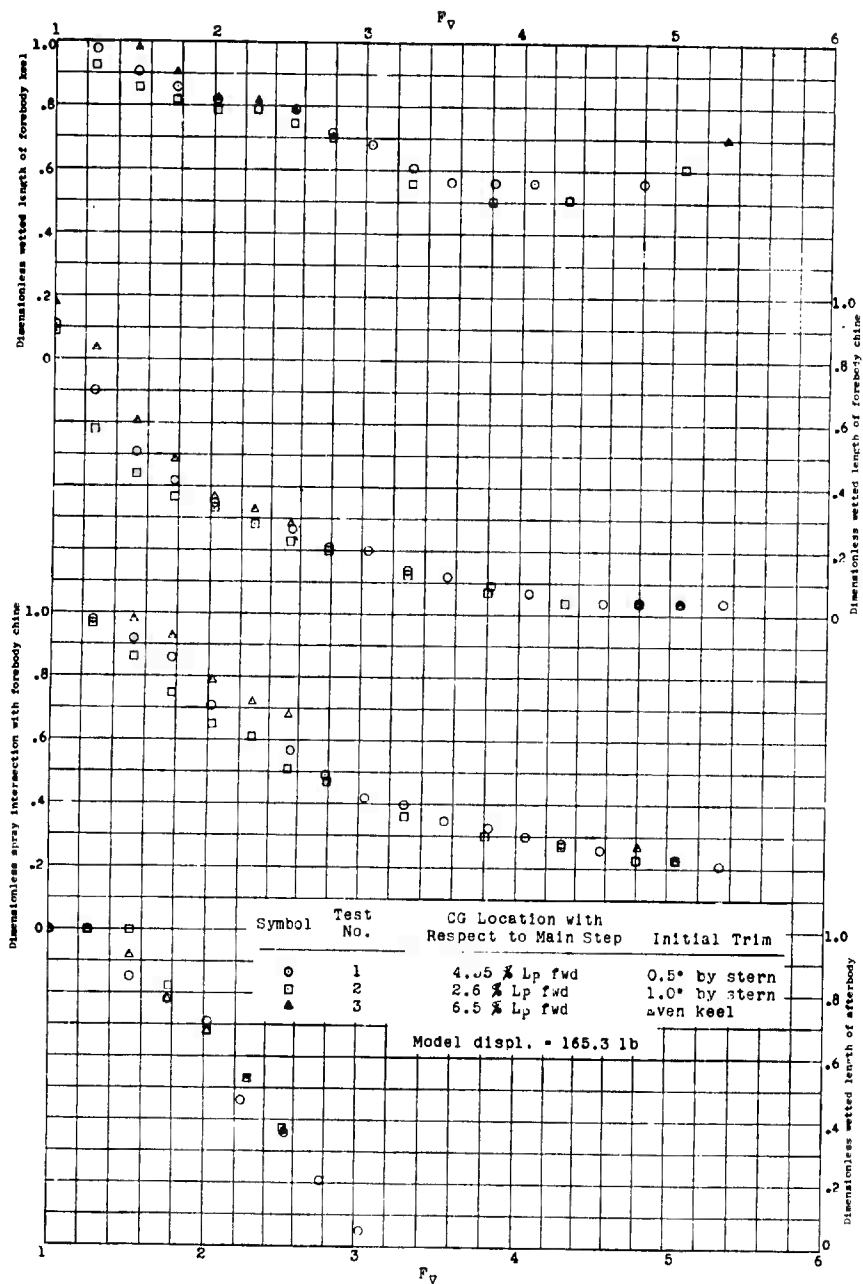Figure 11 - Wetted Lengths for Model 4461-3 at Three LCG Positions, $A_p/\nabla^{2/3} = 6.84$

-21-
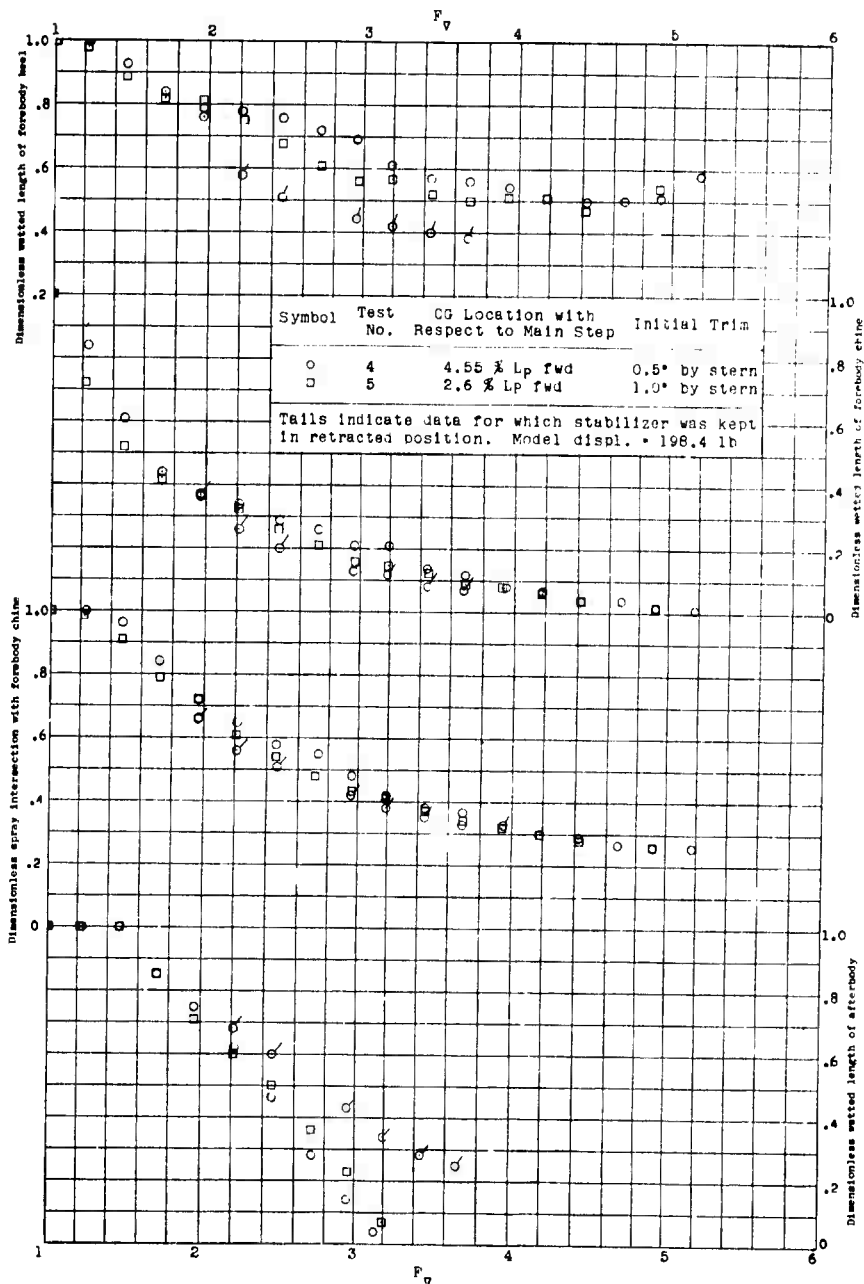
Figure 12 — Wetted Lengths for Model 4461-3 at Two LCG Positions, $A_p/\nabla^{2/3} = 6.05$
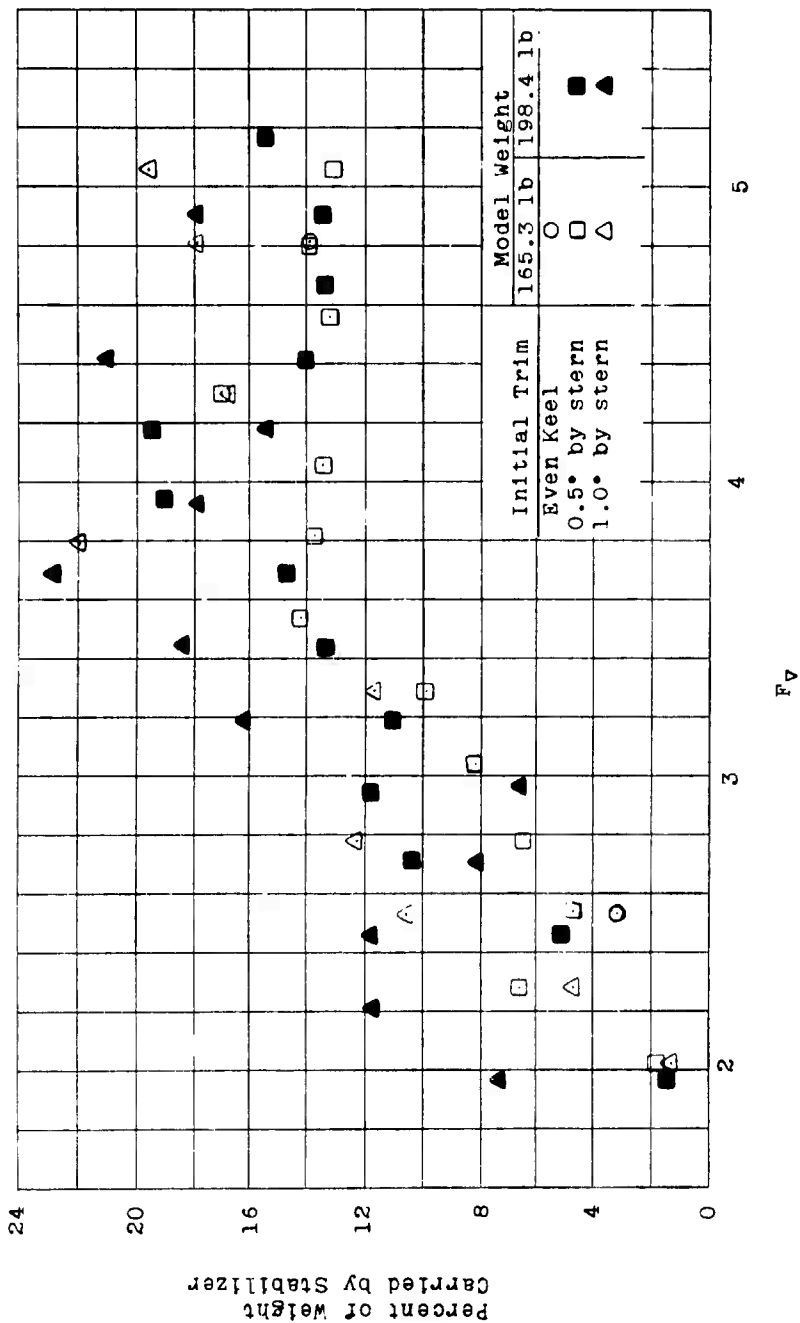
Figure 13 - Percent of Weight Carried by Stabilizer of Model 4461-3
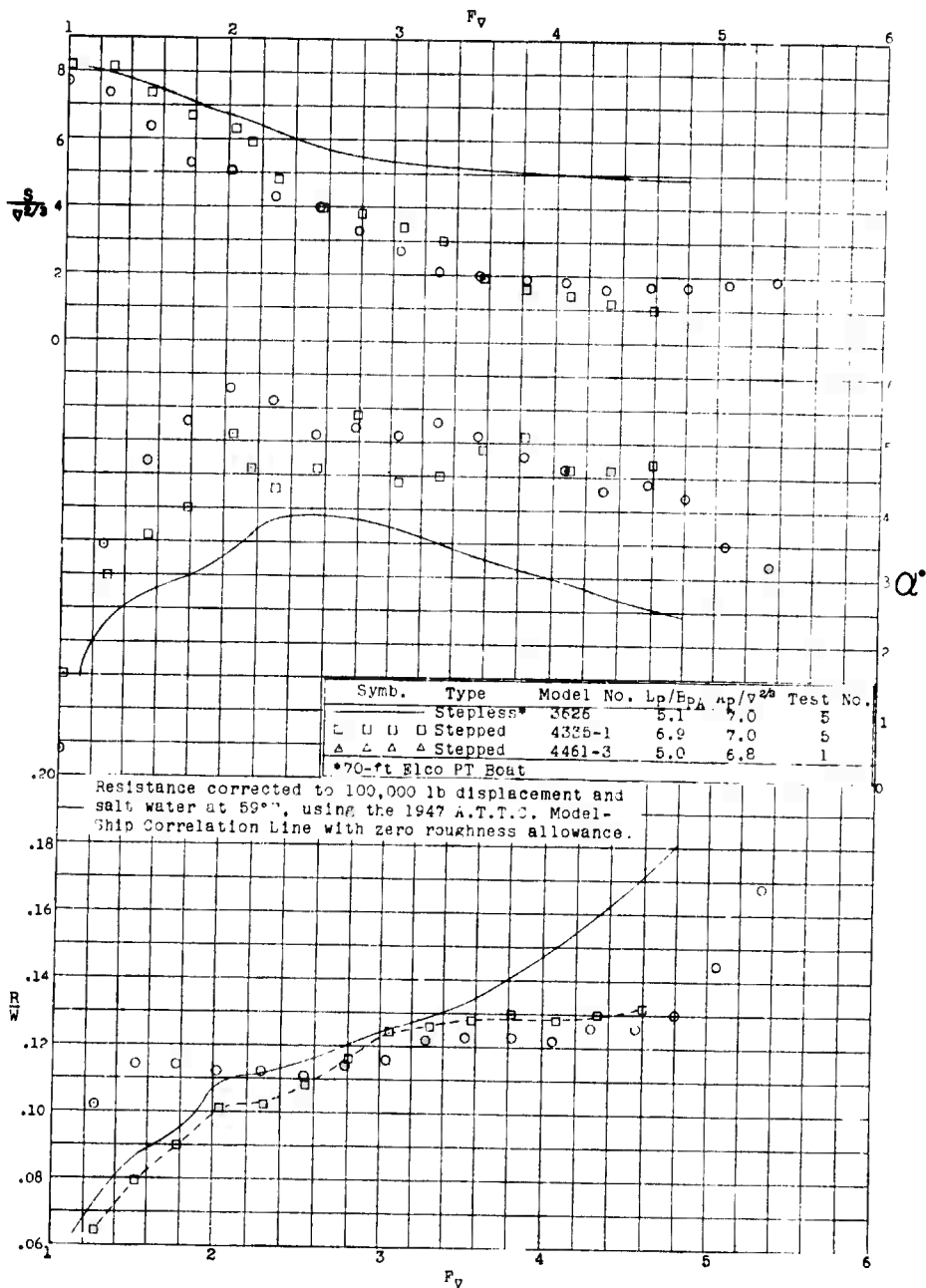
Figure 14 - Comparison of Resistance, α, and Wetted Surface for the
Two Stepped Hulls and a Conventional Planing Boat Design

Symb.	Type	Model No.	L_P/E_{PA}	$\Lambda_P/\nabla^{2/3}$	Test No.
	Stepless*	3626	5.1	7.0	5
⊔ ⊔ ⊔ ⊔	Stepped	4335-1	6.9	7.0	5
△ △ △ △	Stepped	4461-3	5.0	6.8	1

*70-ft Elco PT Boat

Resistance corrected to 100,000 lb displacement and
salt water at 59°F, using the 1947 A.T.T.C. Model-
Ship Correlation Line with zero roughness allowance.

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Two models of stepped planing boats were tested to determine the effect of change in length-beam ratio. The models were tested with the same adjustable stern stabilizer at several loads and LCG locations. The model with the lower length-beam ratio ($L_p/B_{BX} = 3.4$) had considerably more resistance than the other stepped model ($L_p/B_{PX} = 4.7$) at low speed and slightly less resistance at high speed. The resistance of both stepped designs at high speed was considerably less than that of a representative unstepped planing boat design.

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Planing boats						
Adjustable planing stabilizer						
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